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Do Steel Prices Move Together?

A Cointegration Test

Ying Qian

Lack of international comparability in crude steel prices presents a problem in constructing an econometric model of the global steel market.

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This paper — a product of the International Commodity Markets Division, International Economics Department — is part of a larger effort in PRE to investigate the decline since the mid-1970s in the use of metals in the industrial countries. Whether or not this change in industrial countries' demand for metals is permanent is of great importance for the developing country producers of the raw materials. Copies are available free from the World Bank, 1818 H Street NW, Washington DC 20433. Please contact Sarah Lipscomb, room S7-062, extension 33718 (33 pages with figures and tables).

The commonly used measures of crude steel prices are the weighted average of the prices of steel products and the index of the weighted average of prices based on a certain year.

But in the context of constructing an econometric model of the global steel market — a model that treats steel in crude steel equivalent terms — these measures are not comparable internationally.

If the various product prices are cointegrated, it is appropriate to use the price of the most widely produced and traded product in the model (uncoated steel sheet) as an indicator of the general movement of crude steel prices.

This would solve the problem of international comparisons.

Qian tested the cointegration of steel product prices, using import unit values for France and West Germany and survey market prices for the United States.

He concludes that the hypothesis that the price of uncoated steel sheet cointegrates with the prices of other steel products holds in most cases in France and Germany. The same is not true of the United States, which may point to quality problems with the price data.

Use of the price data of uncoated steel sheet as the indicator of crude steel prices in the global steel model would thus seem appropriate for capturing long-term price movements of various steel products.

Using cointegration tests, the paper also investigates the relationship between macroeconomic variables and steel product prices.

Do Steel Prices Move Together?
A Co-integration Test

by
Ying Qian

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I. Introduction[1]

In constructing an econometric model of the global steel market,[2] one of the most challenging questions was how to define the price of steel. Since the model deals with steel in crude steel equivalent terms, all final steel products have to be converted to their crude steel equivalent measures according to their respective conversion coefficients, which are subject to change from time to time. The seemingly correct measure of the crude steel price would be either (i) the weighted average of the prices of steel products, where the weights are the production or consumption quantities of the different steel products in crude steel terms, or (ii) the price index of the weighted average of steel prices based on a certain year.

However, beside the complexity of generating weighted average prices or a price index, these seemingly correct measures suffer a critical weakness in the context of a global model of the steel market. That is, they both lack international comparability. Within the global model, the domestic crude steel prices of each country are used to determine production, consumption and market clearing. These domestic prices are also used to judge market efficiency and international competitiveness. However, the weights applied to construct an aggregate steel price or price index are most likely different for different countries, since the consumption or production patterns for various steel products in different countries are different. For instance, the weighted average price of crude steel for a country which consumes a large percentage of high-quality steel will be higher than for a country which consumes a large percentage of low-quality steel. Thus, the differentials in the constructed prices of crude steel between the two countries can be very misleading.

One solution to the likely inconsistency in crude steel prices is to use a well-defined price of a single steel product in the model, and treat it as the indicator of the general movement of crude steel prices. The advantage of using such a single product price is the

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[1]I would like to thank R. Duncan, T. Palaskas, T. Priovolos and P. Varangis for their valuable comments and editing.

[2]The global steel market model used for policy evaluations and forecasts in the International Commodity Markets Division, The World Bank.

guarantee of international comparability. Therefore, selection of the particular product to fill this role is very important; the price selected should provide an adequate amount of information on the price movements of many steel products within a particular country.

The hypothesis introduced and tested here is that prices of various steel products are cointegrated. If a cointegrated relationship can be established between the price of one steel product and the prices of a wide range of other steel products within a market, then a long run relationship exists between the prices of the steel products; and if the prices of steel products diverge in the short run, they will move back together in the long run.

The justification for suggesting the cointegration hypothesis relies on the concept of the marginal cost of steel production. It is obvious that each steel product has an identifiable market, that substitutability between products can be quite small, and the price of the product can be reasonably responsive to movement in the demand and supply of the product. But an excess demand or supply situation in the market for one product should not drive its price away from the prices of other products for a long period, because the relatively common production processes for steel products make market entry or exit by steel producers relatively easy. The market equilibrium price should reflect the marginal cost of the production in the long run. Because most production processes require the same group of inputs (i.e., iron ore, coke, electricity, labor, and capital), the trend in the marginal costs of steel production should reflect, to a large extent, cost changes in those inputs. Thus, the relativity of marginal costs of different products should remain constant over the long run.

The paper follows the following format. Part II reviews recent literature on cointegration. Part III gives details of the data. The results of the tests for cointegration of steel prices are presented in Part IV. Part V presents a cointegration analysis of the relationship between steel prices and macroeconomic variables. The purpose of this analysis is to see which may be the appropriate macro-economic variables to include in the steel model. Part VI draws conclusions.

II. Stationarity and Cointegration

The properties of a discrete time series variable y_t are crucially dependent on the stationarity of the series. Strict stationarity is defined as: the joint distribution of any finite subset $y_{t1}, y_{t2}, ..., y_{tk}$ depends only on t2 - t1, t3 - t1, ..., tk -t1 and not on t1. Weak stationarity is defined as: the mean $E(y_t) = E(y_s)$ is a constant, and the covariance $COV(y_t, y_s)$ depends only on the distance apart in time (t - s). If y_t is weakly stationary, the variance is finite and both the mean and correlogram of y_t are independent of time. A non-stationary series has variance which explodes with time and any innovations permanently affect y_t so the series does not return to some mean level following a stochastic shock.

The simplest example of a non-stationary series is a random walk:

$$y_t = y_{t-1} + \epsilon_t$$

where ϵ_t is independent and normally distributed. Thus:

$$y_t = \epsilon_t + \epsilon_{t-1} + ... + \epsilon_1, \quad \text{if } y_0 = 0$$

so that y_t is the sum of all the past innovations ϵ_t, no matter how long ago these occurred. Conversely, $y_t - y_{t-1} = \epsilon_t$ is stationary.

If differencing d times is required to produce stationarity, y_t is said to be integrated of order d, or $y_t \sim I(d)$. Most economic variables are seen to be I(1).

There are great differences in appearance between a series that is I(0) and another that is I(1). If $x_t \sim I(0)$ with zero mean then: (i) the variance of x_t is finite; (ii) an innovation has only a temporary effect on the value of x_t; (iii) the expected length of time between crossings of $x=0$ is finite; and (iv) the autocorrelations ρ_k decrease steadily in magnitude for large enough k, so that their sum is finite. If $x_t \sim I(1)$ with $x_0=0$, then: (i) the variance of x_t goes to infinity as t goes to infinity; (ii) an innovation has a permanent effect on the value of x_t, as x_t is the sum of all previous changes; (iii) the expected time between crossings of $x=0$ is indefinite; and (iv) the theoretical autocorrelations $\rho_k \to 1$ for all k as $t \to \infty$. Presented in graphs, the I(1) series is rather smooth, having dominant long periods of swings as compared to an I(0) series which has scattered observations and no appearance of long-term trends. Because of the relative sizes of the variances, it is always true that the sum of an I(0) and an I(1) series will be I(1). Also, if there exist constant scaler c_0 and c_1, with $c_1 \neq 0$, and if x_t~I(d), then $c_0 + c_1 x$ is also I(d).

If x_t and y_t are both I(d), then it is generally true that the linear combination $z_t = x_t - ay_t$ will be I(d). However, it is possible that z_t~I(d-b), b>0. In the special case where d=b=1, so that x_t, y_t are both I(1) with dominant long-term components, z_t is I(0). For a=1, this relationship merely says that the long-term components of x_t and y_t cancel out after first differencing. The use of the constant a suggests that some scaling needs to be used before the I(0) difference can be achieved. If the scaling parameter a exists, it must be unique.[3]

Before testing for a co-integrated relationship within any set of variables, it is necessary to establish that they are all integrated of the same order. The order of integration is inferred by testing for the unit roots. For testing the hypothesis, H_0: x_t~I(1), the following tests may be conducted: (a) The Durbin-Watson test of Sargan and Bhargava (CRDW); (b) The Dickey-Fuller test (DF) and (c) the Augmented Dickey-Fuller test (ADF). Visual inspection of the correlogram may also help to identify whether stationarity exists. The correlogram will soon decrease from positive values to insignificance as the number of lags increases if x_t~I(0); whereas if x_t~I(1), the sample first-order autocorrelation should be close to unity and the correlogram should not radically decrease with increasing lags.

All integration tests are based on simple ordinary least squares regression: $x_t = c + e_t$, where c is the coefficient for the intercept term and the e_t are the residuals. The statistics ξ are defined as follows:

CRDW: H_0: x_t~I(1). $\xi_1 = DW$.

DF: $\Delta e_t = \alpha - \beta e_{t-1} + v_t$

H_0: x_t~I(1). $\xi_2 = \tau_\beta$: the t statistic for ß.

ADF: $\Delta e_t = \alpha - \beta e_{t-1} + \Sigma_{i=1}^{n} \gamma_i \Delta e_{t-i} + v_t$

H_0: x_t~I(1). $\xi_3 = \tau_\beta$: the t statistic for ß.

where n is selected to be large enough to ensure the residuals v_t in the e_t regression are

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[3]As proof, assume there exist two scaling parameters a and b, where a ≠ b. Let $z_t = x_t - ay_t$ and $z_s = x_t - by_t$, both z_t and z_s are I(0). So $z_s - z_t$ is I(0), which implies $(a - b)y_t$ is I(0), thus y_t is I(0).

white noise.

Table 1 below shows the critical values for the three different statistics at the 99%, 95% and 90% significance level. If any of the ξ_i is greater than these critical values, the H_0 can be rejected.

Table 1: Critical Values for Tests of Unit Root

	Levels of Significance		
Statistics	99%	95%	90%
CRDW	0.511	0.386	0.322
DF	4.07	3.37	3.03
ADF	3.77	3.17	2.84

Source: Engle and Granger (1987)

where ADF is performed under the assumption of n=4.

Table 1 was obtained through Monte Carlo simulation based on 100 observations and 10,000 replications under the assumption that Δe_t is independent and normally distributed. If however, Δe_t has a fourth order auto-correlation, that is, $\Delta e_t = \gamma_4 \Delta e_{t-4}$, and $\gamma_4 \neq 0$, then these critical values are subject to change. Table 2 presents the critical values in the case of the auto-correlated Δe_t, where $\gamma_4 = 0.8$. Other conditions for the simulation have not changed.

Table 2: Critical Values for Tests of Unit Root Where Fourth-Order Auto-Correlation Exists

	Levels of Significance		
Statistics	99%	95%	90%
CRDW	0.455	0.282	0.209
DF	3.90	3.05	2.71
ADF	3.73	3.17	2.91

Source: Engle and Granger (1987)

In the non-autocorrelated case, the ADF test is misspecified; therefore, it is expected to be less powerful than the DF test, because it estimates parameters which are truly zero under both the null and the alternative. When autocorrelation is present, the DF test is misspecified and less powerful than the ADF test. The CRDW test performs better overall in both the non-autocorrelated and autocorrelated cases according to the power calculation by Engle and Granger. However, its critical values are sensitive to the particular parameters within the null hypothesis as well as to the sample size, so it cannot be the recommended test under all circumstances. In order to avoid misleading results from the tests, all three tests are applied.

The cointegration test is very similar to the integration test, because both involve the unit root tests. In fact, the same critical values are applicable to both tests.[4] In the special case where both y_t and x_t are found to be I(1), the two-step procedure (Granger-Engle) starts with a cointegration regression:

$$y_t = c + ax_t + e_t$$

where e_t is the residual term. The second step is to test the null hypothesis, H_0: $e_t \sim I(1)$,

[4]As Engle and Yoo (1986) show, the critical values are higher when the sample size is smaller or the number of variables is larger. Thus the critical values for the integration tests should be lower than the critical values for the cointegration tests given the same sample size. Table 1 and Table 2 are derived through simulations on cointegration. For the integration tests, the rejection of the unit root will be at slightly higher levels of significance than the tables suggest.

by applying the standard integration tests.

It has been proved that the estimated parameter $\hat{a}$ of a in the cointegration regression is consistent with the real parameter a (Stock, 1984), and convergence is very rapid. This result implies that if the sample size is relatively large and y_t and x_t are indeed cointegrated in the true data generating process, the two-step procedure of testing cointegration seems to be appropriate. But if the R^2 is low, large biases in $\hat{a}$ are likely, and the two-step procedure is less than fully consistent. Nevertheless, if the R^2 is reasonably high (>0.95) and the DW is not too low in the static regression, the Granger-Engle two-step procedure is clearly of interest.

Finally, cointegration is a very stringent test of the relationship between a pair of variables. If the cointegration test fails, it does not necessarily mean that there is no relationship between the two variables, it may mean that other variables need to be added in order to establish the relationship.

III. Data

Table 3 reveals the percentage of the production of each product in total steel production. Products commonly produced and having a variety of demands in the down-stream industries are listed in the table. Plates, sections, bars and rods are used mainly for construction purposes. Coated or uncoated sheets are applied in the manufacture of automobiles. Tubes and pipes can also be found in automobiles and motorcycles.

Table 3 World Production of Steel Products (in %)

	1970	1975	1980	1985
1. Wire Rod	7.04	7.43	8.71	10.14
2. Big Sections	10.93	4.78	4.73	4.90
3. Small Sections	11.47	11.44	11.83	12.77
4. Heavy Plate	10.99	14 26	12.70	12.47
5. Medium Plate	2.50	2.97	3.13	3.51
6. Cold-Rolled Sheets	11.66	12.25	13.81	16.66
7. Hot-Rolled Sheets	18.60	18.39	15.07	8.92
8. Tinned Plates	2.69	2.43	2.36	2.20
9. Galvanized Sheets	2.63	2.61	3.50	4.68
10. Hoop and Strip	7.16	7.04	7.08	7.06
11. Rails and Track Equ.	1.98	2.20	2.02	2.09
12. Wire (Excl Wire Rod)	3.13	3.17	2.99	1.86
13. Seamless Tube	3.64	4.26	4.73	5.19
14. Welded Tube	5.57	6.78	7.34	7.53
Wire (1+12)	10.17	10.60	11.71	12.00
Non-Flat (2+3+11)	24.38	18.42	18.57	19.76
Flat (4+5+6+7+8+9+10)	56.23	59.94	57.65	55.51
Tube (13+14)	9.22	11.03	12.06	12.72
Total (%)	100.00	100.00	100.00	100.00
Total (Mill. MT)	524.1	535.7	594.4	532.3

Source: U.N., Industrial Statistics Yearbook, Volume II.

Roughly, these products can be categorized into four groups, i.e., Wire, Non-Flat, Flat and Tube, as seen in the bottom part of the table. Flat products constitute more than half of the tonnage of total production in the last 20 years. Cold-rolled sheet has dominated the production line for flat products, especially in recent years, while the relative importance of hot-rolled sheet has declined. These two combined have held a constant 30% share of total production of steel products.

Table 4 displays the percentage of each product in total world steel exports.

Table 4 World Exports of Steel Products (in %)

	1970	1975	1980	1985
1. Wire Rod	6.91	7.36	9.32	8.54
2. Big Sections	7.98	8.84	13.73	9.57
3. Small Sections	4.43	4.86	1.51	1.37
4. Heavy Plate	15.07	15.76	12.22	11.50
5. Medium Plate	2.66	1.62	1.89	2.73
6. Uncoated Sheets	22.87	19.00	14.36	15.26
7. Tinned Plates	4.61	4.12	3.78	3.19
8. Galvanized Sheets	3 01	4.86	8.31	12.41
9. Hoop and Strip	10.82	8.84	9.45	7.97
10. Rails and Track Equ.	1.95	2.36	1.89	1.71
11. Wire (Excl Wire Rod)	6.03	4.57	4.28	5.13
12. Seamless Tube	5.50	7.81	8.19	9.79
13. Welded Tube	8.16	10.01	11.08	10.82
Wire (1+11)	12.94	11.93	13.60	13.67
Non-Flat (2+3+10)	14.36	16.05	17.13	12.64
Flat (4+5+6+7+8+9)	59.04	54.20	50.00	53.08
Tube (12+13)	13.65	17.82	19.27	20.62
Total (%)	100.00	100.00	100.00	100.00
Total (Mill. MT)	56.4	67.9	79.4	87.8

Source: U.N. Trade Analysis and Reporting System.

The total exports of these steel products made up 11% of total production in 1970 and 17% of total production in 1985. The trade data base does not classify the cold-rolled sheet and hot-rolled sheet separately; the two are combined as uncoated sheet. Again, as in Table 3, flat products comprise more than 50% of total exports. Uncoated sheet has the largest percentage of total exports in each year. The percentages for wire, non-flat and flat products in Tables 3 and 4 are more or less the same, with the exception of tubes, where the proportion in total trade is significantly higher than in production. This is because the production of seamless or welded tube requires somewhat sophisticated techniques, which many developing countries do not possess and therefore they must import tubes from the industrial countries, even if they are self-sufficient in or export other steel products.

Because of its importance in production and trade, the price of uncoated steel sheet has been chosen as the likely indicator of the steel price in the global steel model. To test the validity of this choice, cointegration tests have been carried out between the price of uncoated steel sheet and the prices of other steel products. Series of annual steel prices which are considered to be representative of international trade and prices in major domestic steel markets are included in the analysis.

The annual prices included in the cointegration tests are the import unit values of the steel products for France and Germany and domestic prices for the United States. The import unit value(c.i.f.) is essentially the weighted average of all the import transactions for a certain product within a year in a particular country, including the transaction costs, i.e., insurance and freight. The assumption made in order to use the c.i.f. price as the approximation for the domestic price is that the explicit or implicit market distortions in the domestic steel markets are negligible. That is, there is no or a small wedge between the c.i.f. price and the domestic market price. This may well not be the case in many developing countries, where import licenses are usually required. However, for the two major steel-producing industrial countries (i.e., France and Germany) whose import unit values are analyzed in the cointegration test, such distortions may not be large. Both France and Germany are members of ECSC (European Coal and Steel Community) and the EEC. In principle and practice, constraints on steel trade within the community have been eliminated, although there have existed various trade barriers raised by the EEC against the rest of the world.[5] Roughly over 70% of steel imports of these two countries have come from other EEC member countries in recent years. In 1987, Germany and France ranked No. 3 and No. 5 on the list of the world's major steel importers, therefore, distortions should not be very large and the import unit values of steel products should be good approximations for their domestic steel prices.[6] The sample of annual data from TARS[7] is for the period 1962 to 1987 for France and from 1962 to 1988 for Germany. Products considered in the tests are wire rods, bars, big sections, heavy plates and sheets.

The US import unit values for steel products found in TARS are considered to be of poor quality; domestic prices have therefore have been chosen from the publication American Metal Market/Metal Statistics[8] for the following products -- wire rods, bars, galvanized sheets, plates and hot-rolled sheet.[9]

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[5]For example, during different periods there were import quotas, anti-dumping and countervailing actions, import price monitoring and voluntary restraint agreements. Historically, the non-tariff barriers were more important than the tariff barriers, and had the effect of upgrading product qualities and increasing import unit values. The penetration rates of imported steel from the rest of the world increased from 6% in 1974 to 14% in 1987.

[6]The reason that the import unit values of steel products are used as proxies for domestic steel prices is because suitable time series data on domestic prices could not be found for France and Germany.

[7]U.N. Trade Analysis and Reporting System.

[8]A business newspaper published daily by Fairchild Publications, a division of Capital Cities Media Inc.

[9]Sheets can be hot-rolled or cold-rolled. The cold-rolling process takes the hot-rolled sheets as input which undergoes further rolling without pre-heating. Cold-rolled sheet has higher quality than hot-rolled sheet, and is priced higher.

IV. Integration and Cointegration Test Results

Tables 5 to 7 present the integration and cointegration test results on annual French import unit values in current US$ for the five steel products presented. The first columns in these tables give the product names; reading downwards, they are wire rods, bars, big sections, heavy plates and sheets. All CRDW, DF and ADF test results are presented.[10] The auto-correlated lag structures are set to the fourth order, where needed. The value of F(3,20) tests the auto-correlation in the residual terms from the ADF regression. If the F value is larger than the critical value, the joint hypothesis of no first, second or third order auto-correlation in the residual term can be rejected.

The set of three tables is needed to present the results of the cointegration tests on a single group of data. Tables 5 and 6 offer the test results on whether the hypothesis of a unit root can be rejected in the levels and in the first differences, respectively. If the unit root hypothesis can only be rejected in the first differences, the statistical property that the levels are I(1) and their first differences are I(0) can be established. Table 7 provides the statistics to test the hypothesis that the residuals from the cointegration regression have a unit root, i.e., are I(1). If the evidence points to rejection, then a cointegrated relationship between the pair of prices can be confirmed. Results in Table 7 are based on the cointegration regression where the dependent variable is one of the four prices, and the independent variable is the price of uncoated steel sheet.

[10]All three statistics are tested against the unit root hypothesis; as long as one statistic is significant it is sufficient to reject the hypothesis.

Table 5: Integration Tests (French c.i.f.)
Levels (Nominal)
1962 - 1987 (Annual)

Series	CRDW Crit.Val 95% 0.386	DF Crit.Val 95% 3.37	ADF Crit.Val 95% 3.17	Lags(ADF)	F(3,20) Crit.Val 95% 8.66
WRod	0.097	0.654	0.948	1	1.140
Bar	0.115	0.680	0.872	1	0.965
Bsec	0.095	0.511	0.650	1	0.614
Hplt	0.127	0.627	0.934	1	1.253
Sheet	0.139	0.325	0.427	1	0.086

Note: The price data in levels are those shown in Figure 1, Appendix II.

Table 6: Integration Tests (French c.i.f.)
First Diff. of Levels (Nominal)
1962 - 1987 (Annual)

Series	CRDW Crit.Val 95% 0.386	DF Crit.Val 95% 3.37	ADF Crit.Val 95% 3.17	Lags(ADF)	F(3,20) Crit.Val 95% 8.66
Wrod	1.635	3.907	2.905	1	1.125
Bar	1.789	4.220	3.098	1	0.985
Bsec	1.846	4.342	2.867	1	0.570
Hplt	1.664	3.962	4.318	1	0.156
Sheet	1.908	4.467	2.931	1	0.100

Note: The price data in levels are those shown in Figure 1, Appendix II.

Table 7: Cointegration Tests (French c.i.f.)
Levels (Nominal)
1962 - 1987 (Annual)

Series	CRDW Crit.Val 95% 0.386	DF Crit.Val 95% 3.37	ADF Crit.Val 95% 3.17	Lags(ADF)	F(3,20) Crit.Val 95% 8.66	R-Square Coint.Reg W/ Sheet
Wrod	0.885	1.800	1.365	1	0.289	0.971
Bar	1.350	3.076	2.420	1	0.225	0.979
Bsec	1.427	3.418	2.897	1	0.427	0.980
Hplt	1.116	2.837	3.154	1	0.436	0.962

Note: The price data in levels are those shown in Figure 1, Appendix II.

It can be seen that according to CRDW, DF and ADF tests in Tables 5 and 6 that the prices of the five steel products are integrated of order one. The number of lags in the ADF tests are the minimum number of lags necessary to have a white noise residual.

The CRDW statistics in Table 7 point to rejection of the hypothesis of a unit root in the residuals of the cointegration regression. However, it is also essential to evaluate the DF and ADF results since the CRDW's critical values tend to be sensitive to the assumptions made and the properties of the sample data. The data set used in this study is relatively small,[11] therefore one should be careful about these results. The R^2 statistics which are used to judge the appropriateness of the two-step (Granger - Engle) procedure for testing cointegration are presented in the last column of Table 7. Among the DF statistics, only the price of big sections is cointegrated with the price of sheet at the 95% significance level. If the confidence level is lowered to 90%, bar prices can be considered to have satisfied the cointegration requirement. The DF test for heavy plate price is just slightly short of the 90% significance level. The results of the ADF tests also support acceptance of the cointegration hypothesis. The ADF test for the price of big sections is close to the 90% level of significance, and the ADF test is just slightly below the 95% significance level for heavy plate prices.

[11]There are 26 observations for French steel prices. The CRDW critical values in Table 1 and Table 2 were calculated on the basis of simulations on 100 observations.

The results from similar tests on the price levels expressed in real terms, on the logarithm of the nominal prices and on the logarithm of real price levels are set out in Appendix I, Tables AI.1 to AI.9. It can be seen that transformations through deflation and logarithms do not change the stationarity of the variables. The cointegration tests presented in Table AI.3, Table AI.6 and Table AI.9 in the appendix show the comparable results to those in Table 7.

Tables 8 to 10 give the integration and cointegration test results on the German import unit values for the five steel products. The same testing procedure is applied as on the French import unit values.

Table 8: Integration Tests (German c.i.f)
Levels (Nominal)
1962 - 1988 (Annual)

Series	CRDW Crit.Val 95% 0.386	DF Crit.Val 95% 3.37	ADF Crit.Val 95% 3.17	Lags(ADF)	F(3,20) Crit.Val 95% 8.66
WRod	0.120	0.793	0.944	1	1.562
Bar	0.123	0.550	0.703	1	0.714
Bsec	0.095	0.208	0.391	1	0.605
Hplt	0.125	0.061	0.309	1	0.825
Sheet	0.086	-0.343	0.253	1	0.426

Note: The price data in levels are those shown in Figure 2, Appendix II.

Table 9: Integration Tests (German c.i.f.)
First Diff. of Levels (Nominal)
1962 - 1988 (Annual)

Series	CRDW Crit.Val 95% 0.386	DF Crit.Val 95% 3.37	ADF Crit.Val 95% 3.17	Lags(ADF)	F(3,20) Crit.Val 95% 8.66
WRod	1.886	4.533	3.256	1	1.586
Bar	1.833	4.392	3.671	1	0.706
Bsec	1.891	4.541	3.548	1	0.712
Hplt	1.634	3.893	3.819	1	0.635
Sheet	1.453	3.631	3.550	1	0.169

Note: The price data in levels are those shown in Figure 2, Appendix II.

Table 10: Cointegration Tests (German c.i.f.)
Levels (Nominal)
1962 - 1988 (Annual)

Series	CRDW Crit.Val 95% 0.386	DF Crit.Val 95% 3.37	ADF Crit.Val 95% 3.17	Lags(ADF)	F(3,20) Crit.Val 95% 8.66	R-Square Coint.Reg W/ Sheet
WRod	0.603	1.439	1.301	1	0.902	0.934
Bar	0.827	2.470	2.381	1	0.097	0.946
Bsec	0.806	2.144	2.550	1	0.070	0.983
Hplt	1.289	3.428	3.614	1	0.618	0.968

Note: The price data in levels are those shown in Figure 2, Appendix II.

The DF and ADF test results in Tables 8 and 9 comfortably confirm the I(1) properties of these series. Table 10 provides a picture of slightly weaker cointegration relationships among German steel prices than among French prices. The CRDW statistics are highly significant for all products. However, only the heavy plate's DF and ADF tests are significant at the 95% level. The ADF test of the cointegration of big sections with sheet is slightly below the critical value at the 90% significance. The R-squared statistics of the cointegration regressions are high enough to accept the appropriateness of the two-step procedure.

Tables 11 to 13 present the integration and cointegration test results on U.S. market prices of the five steel products.

Table 11: Integration Tests (U.S. Market Price)
Levels (Nominal)
1967 - 1988 (Annual)

Series	CRDW Crit.Val 95% 0.386	DF Crit.Val 95% 3.37	ADF Crit.Val 95% 3.17	Lags(ADF)	F(3,20) Crit.Val 95% 8.66
WRod	0.033	1.006	1.239	1	1.578
Bar	0.134	1.206	1.454	1	0.341
GV. Sheet	0.039	-0.015	0.196	1	0.183
Hplt	0.079	1.151	1.257	1	1.178
Sheet	0.039	0.568	0.977	1	0.177

Note: The price data in levels are those shown in Figure 3, Appendix II.

Table 12: Integration Tests (U.S. Market Price)
First Diff. of Levels (Nominal)

Series	CRDW Crit.Val 95% 0.386	DF Crit.Val 95% 3.37	ADF Crit.Val 95% 3.17	Lags(ADF)	F(3,20) Crit.Val 95% 8.66
WRod	1.398	2.999	1.894	1	1.563
Bar	1.298	2.182	2.722	1	0.686
GV. Sheet	1.799	3.713	2.230	1	0.256
Hplt	1.842	3.802	1.284	1	0.072
Sheet	1.669	3.540	2.390	1	0.027

Note: The price data in levels are those shown in Figure 3, Appendix II.

Table 13: Cointegration Tests (U.S. Market Price)
Levels (Nominal)
1967 - 1988 (Annual)

Series	CRDW Crit.Val 95% 0.386	DF Crit.Val 95% 3.37	ADF Crit.Val 95% 3.17	Lags(ADF)	F(3,20) Crit.Val 95% 8.66	R-Square Coint.Reg W/ Sheet
WRod	0.699	2.055	1.745	1	0.133	0.190
Bar	1.958	4.173	4.369	1	1.429	0.492
GV. Sheet	0.796	1.807	2.194	1	0.707	0.153
Hplt	0.553	1.147	1.579	1	2.531	0.068

Note: The price data in levels are those shown in Figure 3, Appendix II.

In the integration test, unlike French and German steel products, some U.S. prices may not satisfy the DF tests of I(1). in particular, for the bar price, the DF test value is too low to confirm its I(1) property. Nevertheless, the ADF test for the bar price is the highest among the five products, although it is still short of the 90% level of significance. The R-squared statistics of the cointegration regression are low, therefore the unit root tests in Table 13 should be treated with caution. Perhaps only cointegrated relationship in Table 13 is that between bars and sheet.

The unsatisfactory test results on U.S. steel prices could result from the poor quality of the data. As mentioned earlier, it is difficult to find well-defined, comparable and representative prices. The U.S. market prices which are published in various issues of <u>American Metal Market</u> are derived on the basis of survey. Thus, the consistency of prices cannot be guaranteed.

V. Macro-economic Variables and Steel Product Prices

It has always been of interest to economists to understand the relationship between macro-economic variables and the prices of various tradable goods, in order for instance to assist in forecasting. The demand for steel products is a derived demand from the manufacture of final goods. The fluctuations in final goods production directly affect the demand for steel, and thus the price of steel. Applying the concept of cointegration, this part of the paper takes a preliminary look at the relationship between six major macro-economic variables and the five steel prices in the case of Germany F.R. and the United States. The macro-economic variables are Gross Domestic Fixed Investment, GDP, and Value Added in Industry, Manufacturing, Construction and Transportation.

Table 14 and Table 15 present the integration tests for the macro-economic variables for Germany. Table 16 gives the cointegration test results between the German macro-economic variables and the steel product prices.

Table 14: Integration Tests For German Macro Variables
Levels (Nominal)
1962 - 1988 (Annual)

Series	CRDW Crit.Val 95% 0.386	DF Crit.Val 95% 3.37	ADF Crit.Val 95% 3.17	Lags(ADF)	F(3,20) Crit.Val 95% 8.66
Fixed Inv.	0.087	-0.476	0.180	1	0.978
GDP	0.074	-1.062	-0.237	1	0.741
Ind. VA.	0.090	-0.386	0.255	1	0.830
Man. VA.	0.102	-0.868	-0.021	1	1.131
Con. VA.	0.124	0.075	0.622	1	0.769
Trn. VA.	0.086	-0.985	-0.187	1	0.759

Definition: Fixed Inv - Gross Domestic Fixed Investment
GDP - Gross Domestic Product
Ind. VA - Value Added in Industry
Man. VA - Value Added in Manufacturing
Con. VA - Value Added in Construction
Trn. VA - Value Added in Transportation

Table 15: Integration Tests For German Macro Variables
First Diff. of Levels (Nominal)
1962 - 1988 (Annual)

Series	CRDW Crit.Val 95% 0.386	DF Crit.Val 95% 3.37	ADF Crit.Val 95% 3.17	Lags(ADF)	F(3,20) Crit.Val 95% 8.66
Fixed Inv.	1.043	2.372	3.125	1	0.339
GDP	1.002	1.998	2.754	1	0.424
Ind. VA.	1.187	2.951	3.249	1	0.231
Man. VA.	0.860	1.982	2.944	1	0.459
Con. VA.	1.062	2.561	3.178	1	0.240
Trn. VA.	0.886	2.046	2.812	1	0.404

Table 16: Cointegration Tests Between Steel Product Prices and Macro Variables in Germany 1962 - 1988 (Annual)

	Gross Fixed Investment	GDP	Value Added Industry	Value Added Manufact.	Value Added Transport.	Value Added Construct
WRod						
CRDW	0.635	0.517	0.897	0.779	0.756	1.294
DF	1.382	1.156	1.754	1.166	1.290	2.864
ADF	1.186	1.068	1.351	1.000	1.021	2.890
Bar						
CRDW	0.808	0.666	0.941	0.834	0.797	1.237
DF	2.173	1.890	1.942	1.389	1.502	2.827
ADF	2.108	1.816	2.072	1.584	1.559	3.378
Bsec						
CRDW	0.852	0.626	1.043	0.847	0.943	1.377
DF	2.018	1.471	2.387	1.463	1.789	3.354
ADF	1.725	1.040	1.985	1.201	1.194	3.573
Hplt						
CRDW	1.131	0.941	1.012	0.912	0.905	1.265
DF	3.025	2.642	2.311	1.749	1.851	3.061
ADF	3.524	2.836	3.517	2.537	1.634	4.628
Sheet						
CRDW	0.712	0.516	0.801	0.614	0.788	0.703
DF	1.955	1.223	2.949	1.310	1.913	2.437
ADF	2.252	1.068	2.692	1.252	1.394	3.525

From the ADF tests in Table 15, all German macro-economic variables seem to be I(1). Recall that Table 9 indicated that all German steel prices are also I(1); it is appropriate, therefore, to conduct the cross-sectional cointegration test between the macro-economic variables and steel prices.

In Table 16, the value added of the construction sector has the best fit with steel prices in terms of cointegration. Tests on four out of five steel prices have a 95% significance level in the DF or ADF statistics; the ADF test for wire rod is significant at the 90% level. These results indicate the importance of the German construction sector for steel demand. In particular, the demand for construction materials such as wire rod, bar and big sections is heavily influenced by the activity of the construction sector.

Other noteworthy relationships in Table 16 are the 90% significance level for the cointegration of steel sheet price with the industry value added, and the 95% significance level of the relationships between heavy plate and gross domestic fixed investment and between heavy plate and industry value added. Steel sheet is used in almost every sector of industry. It may not be strongly associated with the performance of any one sector, but industry's overall performance should forcefully affect its demand. Heavy plate is primarily used in construction and machinery manufacture, so it is not a surprise to see that it is cointegrated with gross domestic fixed investment, which involves new production facilities, equipment and machinery.

Tables 17 to 19 present the tests of the relationships between U.S. macro-economic variables and the five steel prices.

Table 17: Integration Tests For U.S.A. Macro Variables
Levels (Nominal)
1967 - 1988 (Annual)

Series	CRDW Crit.Val 95% 0.386	DF Crit.Val 95% 3.37	ADF Crit.Val 95% 3.17	Lags(ADF)	F(3,20) Crit.Val 95% [illegible].66
Fixed Inv.	0.030	-2.542	-0.416	1	1.383
GDP	0.021	-7.305	-3.130	1	0.946
Ind. VA.	0.022	-2.475	-1.627	1	1.487
Man. VA.	0.024	-2.331	-1.938	1	0.297
Con. VA.	0.028	-4.229	-1.491	1	3.000
Trn. VA.	0.020	-5.600	-2.087	1	0.221

Table 18: Integration Tests For U.S.A. Macro Variables
First Diff. of Levels (Nominal)
1967 - 1988 (Annual)

Series	CRDW Crit.Val 95% 0.386	DF Crit.Val 95% 3.37	ADF Crit.Val 95% 3.17	Lags(ADF)	F(3,20) Crit.Val 95% 8.66
Fixed Inv.	1.257	3.362	2.982	1	0.073
GDP	0.468	1.769	1.222	1	2.614
Ind. VA.	1.410	3.493	2.708	1	2.094
Man. VA.	1.691	4.028	2.853	1	0.672
Con. VA.	0.611	1.910	2.313	1	0.304
Trn. VA.	0.618	2.161	1.489	1	0.483

Table 19: Cointegration Tests Between Steel Product Prices and Macro Variables in U.S.A. 1962 - 1988 (Annual)

	Gross Fixed Investment	Value Added Industry	Value Added Manufact.
WRod			
CRDW	0.309	0.303	0.342
DF	0.719	0.627	0.698
ADF	1.249	0.863	1.021
Bar			
CRDW	1.209	1.539	1.473
DF	1.988	3.073	2.848
ADF	1.929	3.739	3.468
GV. Sheet			
CRDW	0.421	0.669	0.643
DF	0.974	1.510	1.440
ADF	2.077	1.556	1.566
Hplt			
CRDW	0.392	0.479	0.493
DF	0.796	0.879	0.960
ADF	1.738	1.297	1.408
Sheet			
CRDW	0.390	0.551	0.560
DF	0.619	0.860	0.940
ADF	2.138	1.860	1.872

According to Table 17 and Table 18 the I(1) property of some U.S. variables is questionable, specifically GDP, value added in the construction sector and value added in the transportation sector. Thus, tests for cointegration between steel prices and these macro-economic variables may be invalid econometrically and therefore are not conducted.

None of the cointegration relationships in Table 19 are significant, except that between the price of bars and value added in industry and in the manufacturing sectors. However, remember that the bar price itself may not qualify for I(1), according to Table 12, therefore the meaning of these two significant test statistics is ambiguous. It appears that other variables may have to be added in order to derive the appropriate relationship between these macro-economic variables and steel prices in the United States.

VI. Conclusions

The testing of the cointegration hypothesis in respect of steel prices is carried out based on the concept of stationarity and tests for existence of the unit root. Three different unit root tests -- CRDW, DF and ADF -- are applied in order to take account of the advantages and disadvantages of each. The appropriateness of the Granger-Engle two-step procedure is also given attention in the interpretation of the test results.

Import unit values for five major steel products in two major steel-producing countries (i.e., France and Germany F.R.), and domestic steel prices for these similar products in the United States, are used in the test of the cointegration hypothesis. The test results on the French and German steel prices are persuasive. Three out of four prices for France and two out of four prices for Germany are cointegrated with the price of uncoated steel sheet at the 90% significance level. The test results on U.S. prices do not support the cointegration hypothesis. Only one product price cointegrates with the steel sheet price. However, there is a question about the quality of the U.S. price data which has been collected by survey.

The cross-sectional cointegration tests between macro-economic variables and steel prices in Germany and the United States give some interesting results, particularly in the case of Germany. They assert strongly, in econometric language, the importance of steel use in many sectors of the economy. The cross-sectional cointegration tests for the U.S. economy give ambiguous results. They suggest that the relationships between the macro-economic variables and steel prices in the United States can be very complicated. It appears, therefore, that the relationships established in one country do not necessarily hold in another. However, the quality of U.S. steel prices is likely to have affected the estimated relationship between macroeconomic variables and steel prices in the United States.

It is concluded that the hypothesis that the price of uncoated steel sheet cointegrates with the prices of other steel products does hold in some industrial countries. Use of the price of uncoated steel sheet as the indicator of crude-steel prices in the global steel model would seem appropriate to capture the long-term price movements of various steel products in these countries while ensuring international comparability.

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Appendix I

Table AI.1: Integration Tests (French c.i.f.)
(Levels, Deflated by WPI)
1962 - 1987 (Annual)

Series	CRDW Crit.Val 95% 0.386	DF Crit.Val 95% 3.37	ADF Crit.Val 95% 3.17	Lags(ADF)	F(3,20) Crit.Val 95% 8.66
Wrod	0.291	1.405	1.230	1	0.201
Bar	0.617	2.129	1.522	1	0.329
Bsec	0.426	1.848	1.501	1	0.566
Hplt	0.755	2.317	2.393	1	0.547
Sheet	1.168	2.990	2.082	1	0.030

Table AI.2: Integration Tests (French c.i.f.)
(First Diff. of Levels, deflated by WPI)

Series	CRDW Crit.Val 95% 0.386	DF Crit.Val 95% 3.37	ADF Crit.Val 95% 3.17	Lags(ADF)	F(3,20) Crit.Val 95% 8.66
Wrod	2.566	6.305	3.219	1	0.074
Bar	2.754	7.080	4.519	1	0.038
Bsec	2.532	6.188	4.038	1	0.551
Hplt	2.163	5.085	5.657	1	0.169
Sheet	2.736	6.926	4.331	1	0.362

Table AI.3: Cointegration Tests (French c.i.f.)
(Levels, Deflated by WPI)
1962 - 1987 (Annual)

Series	CRDW Crit.Val 95% 0.386	DF Crit.Val 95% 3.37	ADF Crit.Val 95% 3.17	Lags(ADF)	F(3,20) Crit.Val 95% 8.66	R-Square Coint.Reg W/ Sheet
WRod	0.595	1.952	1.885	1	0.307	0.447
Bar	0.962	2.802	2.370	1	0.522	0.489
Bsec	0.679	2.690	2.370	1	1.353	0.522
Hplt	0.889	2.510	2.987	1	0.435	0.333

Table AI.4: Integration Tests (French c.i.f.)
(Levels of the Log, Nominal)
1962 - 1987 (Annual)

Series	CRDW Crit.Val 95% 0.386	DF Crit.Val 95% 3.37	ADF Crit.Val 95% 3.17	Lags(ADF)	F(3,20) Crit.Val 95% 8.66
WRod	0.057	0.651	1.072	1	0.564
Bar	0.070	0.703	0.932	1	0.319
Bsec	0.054	0.649	0.791	1	0.182
Hplt	0.080	0.631	1.019	1	1.385
Sheet	0.074	0.312	0.506	1	0.021

Table AI.5: Integration Tests (French c.i.f.)
(First Diff. of Levels of the Log, Nominal)

Series	CRDW Crit.Val 95% 0.386	DF Crit.Val 95% 3.37	ADF Crit.Val 95% 3.17	Lags(ADF)	F(3,20) Crit.Val 95% 8.66
WRod	1.396	3.464	2.811	1	0.447
Bar	1.633	3.898	3.128	1	0.209
Bsec	1.660	3.951	2.870	1	0.140
Hplt	1.538	3.729	4.110	1	0.022
Sheet	1.693	4.014	2.692	1	0.020

Table AI.6: Cointegration Tests (French c.i.f.)
(Levels of the Log, Nominal)
1962 - 1987 (Annual)

Series	CRDW Crit.Val 95% 0.386	DF Crit.Val 95% 3.37	ADF Crit.Val 95% 3.17	Lags(ADF)	F(3,20) Crit.Val 95% 8.66	R-Square Coint.Reg W/ Sheet
WRod	0.673	1.596	1.362	1	0.216	0.978
Bar	1.150	2.829	2.229	1	0.382	0.984
Bsec	0.858	2.447	2.186	1	0.422	0.984
Hplt	0.918	2.480	2.827	1	0.175	0.971

Table AI.7: Integration Tests (French c.i.f.)
(Levels of the Log, deflated by WPI)
1962 - 1987 (Annual)

Series	CRDW Crit.Val 95% 0.386	DF Crit.Val 95% .37	ADF Crit.Val 95% 3.17	Lags(ADF)	F(3,20) Crit.Val 95% 8.66
Wrod	0.281	1.372	1.249	1	0.207
Bar	0.587	2.065	1.509	1	0.336
Bsec	0.369	1.723	1.444	1	0.515
Hplt	0.693	2.198	2.305	1	0.582
Sheet	1.179	3.019	2.136	1	0.030

Table AI.8: Integration Tests (French c.i.f.)
(First Diff. of Levels of the Log, deflated by WPI)

Series	CRDW Crit.Val 95% 0.386	DF Crit.Val 95% 3.37	ADF Crit.Val 95% 3.17	Lags(ADF)	F(3,20) Crit.Val 95% 8.66
WRod	2.484	6.016	3.282	1	0.042
Bar	2.708	6.882	4.526	1	0.026
Bsec	2.457	5.939	3.889	1	0.483
Hplt	2.122	4.983	5.438	1	0.187
Sheet	2.723	6.867	4.380	1	0.396

Table AI.9: Cointegration Tests (French c.i.f.)
(Levels of the Log, deflated by WPI)
1962 - 1987 (Annual)

Series	CRDW Crit.Val 95% 0.386	DF Crit.Val 95% 3.37	ADF Crit.Val 95% 3.17	Lags(ADF)	F(3,20) Crit.Val 95% 8.66	R-Square Coint.Reg W/ Sheet
WRod	0.588	1.954	1.924	1	0.330	0.446
Bar	0.924	2.737	2.353	1	0.549	0.493
Bsec	0.603	2.568	2.271	1	1.152	0.509
Hplt	0.856	2.448	2.861	1	0.315	0.358

Appendix II

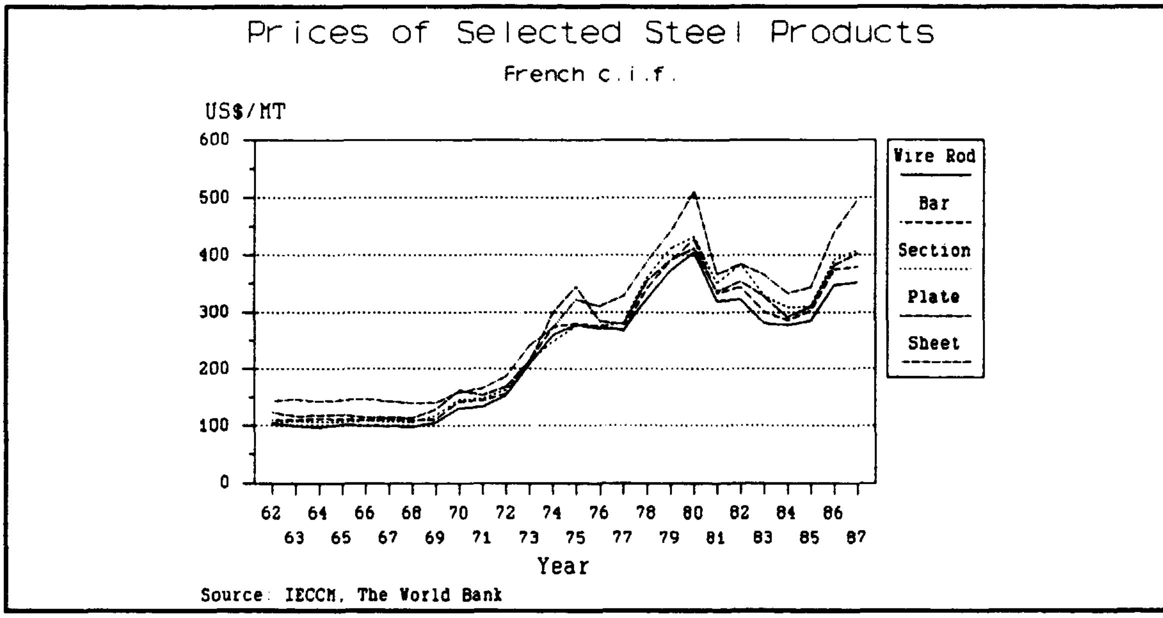

Figure 1

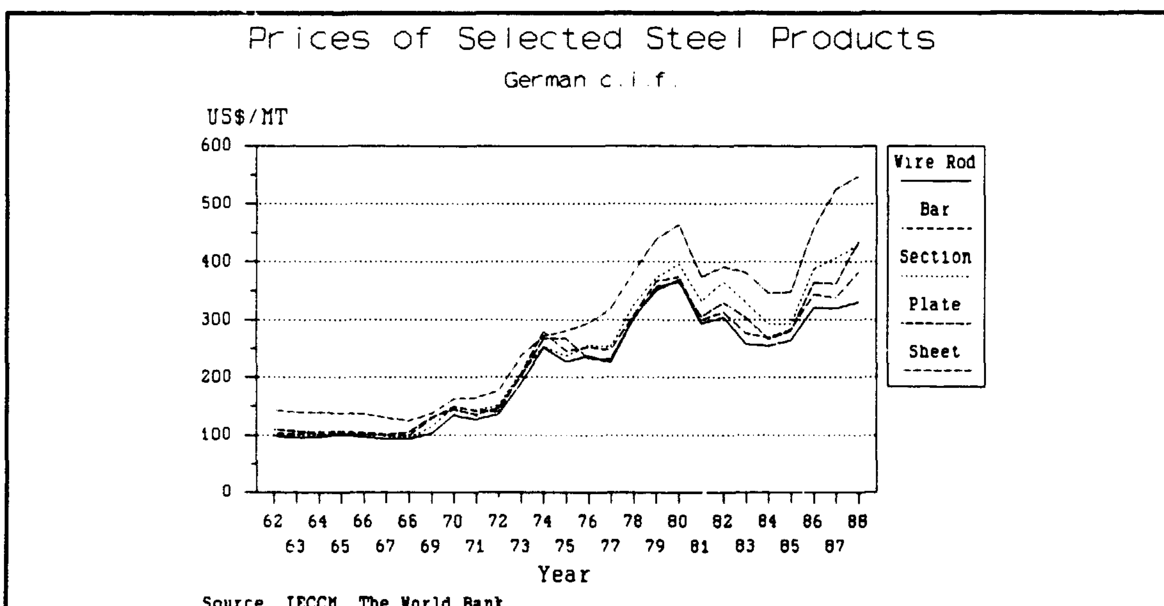

Figure 2

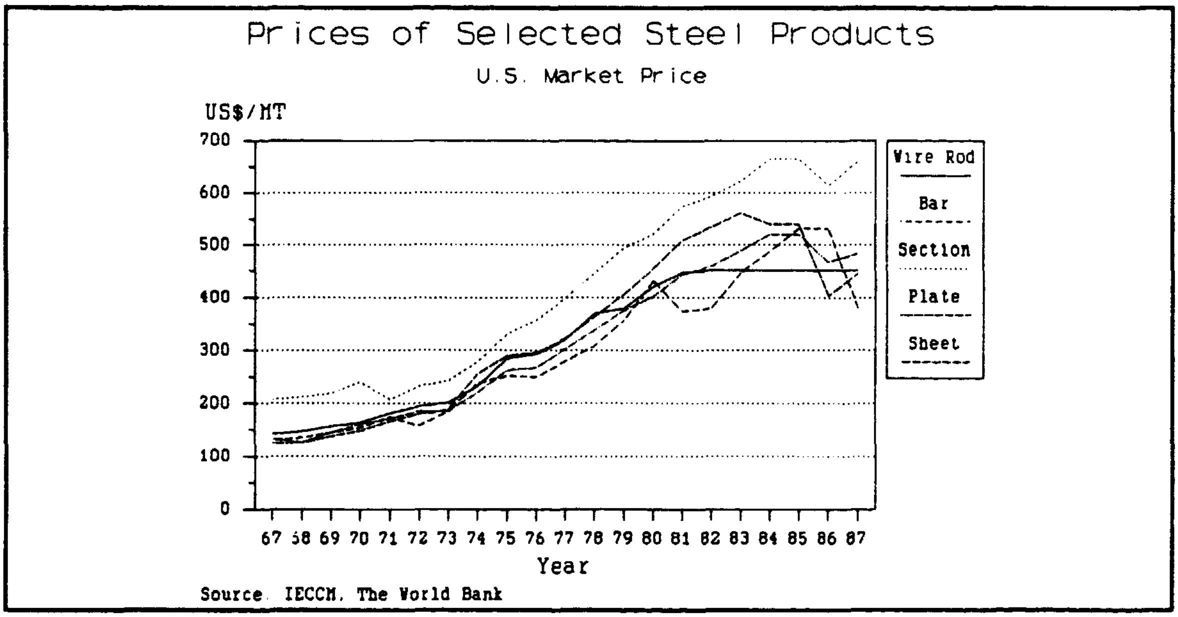
Prices of Selected Steel Products
U.S. Market Price
US$/MT
700
600
500
400
300
200
100
0
67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87
Year
Source. IECCM. The World Bank
Wire Rod
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Figure 3

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